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Study on small simulation device of coal spontaneous combustion process

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Abstract

Considering advantages and disadvantages of present ignition stations, the double nested spontaneous furnace with better thermal insulation performance was developed, and electrical sand bath was taken as thermal insulation and gas preheating device, also the temperature acquisition and temperature control device with higher accuracy was selected in order to solve the problems of heat dissipation and temperature control. The ignition furnace and sand-bath attemperator of the device form the double insurance to protect the heat in the process of the coal spontaneous combustion reaction, and could guarantee the coal spontaneous combustion reaction process to be simulated scientifically and veritably. With this device, the coal sample of the SHIGANG COAL MINE was experimented to simulate the spontaneous combustion reaction process, proving that the device is feasible. The device can be used in the relevant experiments of coal spontaneous combustion.

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Keywords: period of coal spontaneous combustion; experimental simulation; coal combustion; simulator

Coal spontaneous combustion is an extraordinary serious natural disaster in China, which mainly occurred in the coal mines and various types of coal pile, even during coal transportation. More than half of key coal mines have a serious spontaneous combustion phenomenon. It not only seriously affects mine production, resulting in significant economic and resource losses, more importantly, the development of coal spontaneous combustion will lead to external fire, casualties, and even gas explosion, cause heavy casualties and more losses [1]. The coal resources today account for about 70% in the structure of energy production and consumption, and will remain more than 50% in 2050 in prediction. But the fire caused by

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the coal is very serious in our country. The mines which are in danger of spontaneous combustion account for 53.1% of the state-owned key coal mines. And also the fires caused by spontaneous combustion account for more than 90%. It is seriously threating the safety of people's life and property, hindering the sustainable development of coal industry, affecting social stability.

The occurrence and development of coal spontaneous combustion is an extremely complex, dynamic, auto-acceleration physical and chemical processes, and its essence is a process of slow auto-oxidation, heating, warming and until burning [2]. The test of spontaneous combustion period provides basic information to the coal spontaneous combustion law and fire-extinguished in field [3]. Thus, the development of scientific and rational testing device for coal spontaneous combustion has an important role in fire prevention and control.

1. The present situation of small coal spontaneous combustion device

Nearly 20 years, the world's major coal-producing countries have established static simulation of coal spontaneous combustion table to simulate the law of coal self-heating, spontaneous combustion. The more prominent and mature insulation test equipment in all these devices is in the University of Queensland [4], Australia, while in China, since 2003, China University of Mining And Technology have developed a comprehensive insulation test of coal spontaneous combustion system, which has achieved a simulation of the adiabatic oxidation process of coal spontaneous combustion. Basically, a small coal spontaneous combustion simulator can be divided into the reactor body, the temperature control system, temperature acquisition system and gas analysis systems, and each part’s working principle is basically the same, load capacity is approximately 2g~10kg. However, because of their small load capacity, small heat production, for the whole reaction process is affected by wind, heat dissipation.

If it needs to reflect the real reaction process of coal spontaneous combustion, measure the true of minimum ignition period, the oxidation furnace temperature measurement accuracy must be high, the insulation and temperature control system should use inverter technology, gas flow must be controlled as reasonable and accurate as possible, and the measure of preheating inlet pipe should be completed.

2. The device of coal spontaneous combustion

During the process of device designation, the characteristics and problems of current domestic and international device have been analyzed sufficiently, for example the insulation system problems and preheating inlet pipe problems. So the design follows these principles:

- Inlet air temperature rises with the coal temperature, and air flow is less than 200ml/min to prevent excessive heat loss;
- Good insulation environment and thermal systems to reduce heat exchange;
- Accurate temperature measurement system, and the accuracy should reach 0.1℃, recording must be in time for easy data storage, output and printing;
- Gas analysis equipment has enough precision to ensure rapid and accurate analysis for the gas which is generated by spontaneous combustion.
- The device has the appropriate size for transportation and multiple comparison test.

2.1. Spontaneous combustion reaction furnace

The reaction furnace is used for filling coal, and it is divided into two parts: the internal furnace and external furnace. These two parts are cylindrical. The external furnace with the outer diameter of 240mm, and coal loading height is 400mm. And the internal furnace with the inside diameter of 90mm, coal

loading height is 150mm. The maximum of coal loading is 1kg and 12kg. Internal and external furnace structure is shown in Fig. 1.

Furnace is made of steel, and there are flange structures on furnace. To ensure the insulation environment, used high temperature asbestoses. The wire meshes are fixed in the bottom by steel bar. The bottom of air can be more evenly reaction after it into the furnace space, and there is air buffer layer at the top and bottom of furnace, so that the air flow can through the experimental coal evenly. Both furnaces are placed the same coal inside for the same experiment, and the process of spontaneous combustion is under the same conditions, in theory, the whole process keeps pace, and no heat exchange. External furnace is controlled by sand-bath which has a temperature monitoring device, only collecting the temperature and gas in the internal furnace.

2.2. Sand-bath device

Sand-bath device is made in Jintan, Zhejiang, and the model is MT45, the dimensions is 820×700×880 mm. And the volume is 252L, heating power is 4.5kw. With 100mm fiberglass insulation surrounded, maximum heating temperature is 800℃, use 40 mesh industrial sand. It is shown in Fig. 2.

Sand temperature is controlled by temperature controller, whose role is to track the external furnace temperature to ensure the sand temperature to increase simultaneously with the external furnace temperature, reduce the temperature to spread out, and provide heat environment.

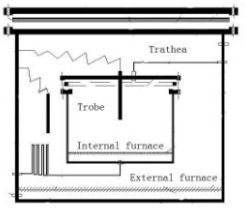

Fig.1. Spontaneous combustion reactor structure

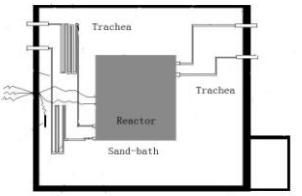

Fig.2. Sand-bath device and reactor structure

2.3. Temperature acquisition system

Temperature acquisition system consists of temperature sensors, temperature control module, the signal transfer module and the computer. Temperature measurement probe has used of pt100 temperature sensor, the effective temperature range of 0~650 ℃, display accuracy 0.1 ℃, and reaction speed is fast. Temperature acquisition module and the signal transfer modules are high-precision six-channel acquisition module, and the temperature acquisition module 7015 is able to collect temperature signal which is collected by temperature sensors, and operate the signal, then the signal is transmitted to the signal transfer module 7520, which transforms temperature signals into signal which will be able to be recognized by computer and then spread to the computer. It is shown in Fig. 3. In cooperation with the dcon_utility and ez_data_logger_v433 software, the device can simultaneously collect and storage the temperature signal of six groups of temperature sensors on the computer. So that we can monitor the reaction process of coal spontaneous combustion and make further analysis on the reaction. The results could output in EXECL and TXT format, support for printing.

2.4. Temperature compensation system

Consists of two parts: temperature controller and gas section. The former is for keeping the sand-bath temperature with the external furnace always in the same, while the latter is for preventing the airflow to bring the furnace heat away.

Temperature controller is made in Xiamen, the model is MT, which consists of pt100 temperature sensor, the temperature control module, silicon voltage regulator, fuse, temperature transmitters and other components, as shown in Fig. 4. Always make the sand-bath temperature track the coal temperature, and thus to control the external furnace has no temperature difference between inside and outside.

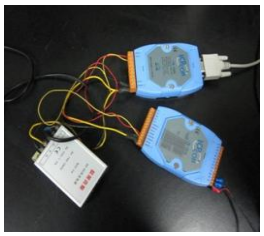

Fig.3. Temperature collection module

Fig.4. Temperature controller

Fig.5. Installations in the pre heat road

Preheat gas has solved the problem of the intake air temperature and reaction temperature are inconsistent, make sure they have the same temperature.

There are two gas circuits into the device: one through the sand then arrives at the external furnace, the other through the sand and external furnace and then arrives at the internal furnace, as shown in Fig. 5.

2.5. Gas supply system

Gas supply system consists of an oxygen tank, air tanks, gas piping, air mixer components. Oxygen and air through the gas pipeline by the control of flow meter, and then mixed in the mixer components. The gas volume distribution is based on the different amount of coal. Well-mixed gases will be divided into two parts: one through the sand to be preheated and access to the external furnace, after coal oxygen reaction and the gas discharged outside device by copper. The flow rate is 150ml/min. The other is going to a second preheat and access to internal furnace. The gas which produced by reaction is determined by gas chromatography with flow rate 2.5L/h.

2.6. Gas analysis system

Gas analysis is mainly complete by GC1100 gas chromatograph. Gas passes into the gas chromatograph and is analyzed the content of CO, CH_4, CO_2. Based on these data, we can know the release pattern of gas.

3. Simulation experiment

Through experiment we can verify the feasibility of the device.

3.1. Experimental conditions

Coal collection method: cut the new coal in working face, and then wrap them tightly in brown paper

and seal them with yellow tape, 10kg for a package，finally freeze them in the laboratory until the beginning of the experiment. Experimental conditions are shown in Table 1 and Table 2.

In the heating process of coal spontaneous combustion, the furnace temperature and gas concentration changed with reaction time, air flow and thermal condition.

Table 1. Coal sample screening test results table

Size/mm	Frequency/%
-1	18.7
-3,+1	17.6
-5,+3	20.8
-8,+10	22.4
+10	20.5

Table 2. Experimental conditions

coal	Size/mm	Coal high(inside/outside) /cm	Coal weight(inside/outside) /kg	Coal volume(inside/outside)/cm^3
Shigang mine	3.1	8/30	0.5/7.5	250/3780
Porosity	Weight/g/cm^3	density/g/cm^3	Wind(inside/outside) /m^3/h	Initial temperature /℃
0.26	1.13	1.47	20~160/300~2400	23.3

3.2. Results

The experiment has started on September 5, 2010, and ended on October 8. The furnace temperature rose from 23 ℃ to 330 ℃, which spent 34 days. Coal temperature reached 330℃. The whole process, the furnace temperature and gas concentration have changed with the time, air flow and heat dissipation condition. The relationship between temperature and time has been shown in Fig. 6, heating rate and coal temperature shown in Fig. 7.

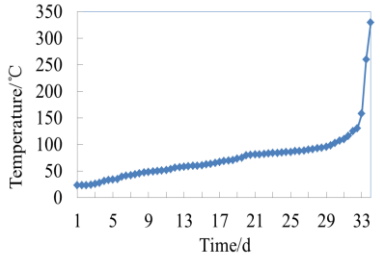

Fig.6. Coal temperature over time variations

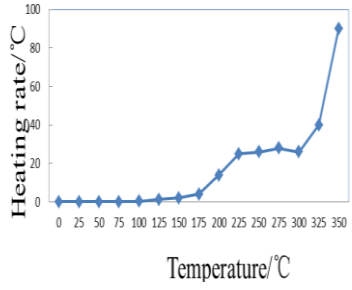

Fig.7. Heating rate with coal temperature

From the experimental results we can conclude: the device can actually simulate the coal spontaneous combustion, after winding for more than 20 days, the oxidation heating began to accelerate, the temperature is 75~80℃ (Critical Temperature), after oxidation for more than 30 days, the rapid of

oxidation heating accelerate quickly, and the corresponding temperature of the coal is 105~110 ℃ (dry temperature); Air time for more than 33 days, corresponding to the coal temperature is 145~150℃ (inflection point temperature), 34 days later, the coal temperature up to 330℃ (ignition point), which is basically consistent with field data. After stopping for air, at a high temperature stage, coal temperature decreases very fast, when coal temperature down to 150℃, the temperature rate of decline has slowed down significantly, and when the coal temperature below 100℃, the day down only 1~2℃.

4. Conclusions

Based on the coal spontaneous combustion mechanism and coal spontaneous combustion process, we have comprehensively studied coal spontaneous combustion from the heat insulation of device, choice of temperature control and experiment. The main research results and conclusions are as follows:

- Designed double-layer structure of the coal reactor, and make sure the reactions are simultaneous and keep temperature equal, solved the problem of heat loss;
- Developed sand-bath which has a greater temperature range and better thermal properties. With double-layer reactor, formed double insurance to the temperature of internal reactor;
- Experimental results show that this device successfully simulated the process of coal spontaneous combustion, the insulation is good, and temperature control is also precise.

References

[1] Lu W, Hu Q T, Zhong X X. et al. Gradual self-activation reaction theory of spontaneous combustion of coal. *Journal of China University of Mining & Technology*. 2007, 36(1): 111~115. (in Chinese)

[2] Wang H, Wen H, Ge L M. The design and implement of automatic control system for large-scale coal spontaneous combustion experiment unit. *Journal of Xi'an University of Science and Technology*, 2008, 28(1):6~10. (in Chinese)

[3] Deng J, Xu J C, Ruan G Q, et al. Review of the prediction and forecasting techniques of coal self-heating both at home and abroad. *Journal of Xi'an Mining Institute*, 1999, 19(4): 293-297, 337. (in Chinese)

[4] Xu J C, Wen H, Gou X M. On index of self combustion tendency of coal by spontaneous combustion experiment. *Journal of xi'an mining institute*, 1997, 17(2):103~107, 126. (in Chinese)